Social Network Analyses (SNA) as a method to study the structure of contacts within teams of a school for secondary education

Celeste Meijs, Maarten de Laat
Ruud de Moor Centrum, Open Universiteit Nederland, celeste.meijs@ou.nl, maarten.delaat@ou.nl

Abstract
This paper reports findings from a study using social network analysis techniques to understand social learning relationships within and between teacher teams in a large secondary school in the Netherlands (n=117 teachers). The findings suggest a relationship between the social structure of a team and their preferred way of learning and it highlights the impact certain functions or positions in a school can have on the ability to develop social relationships. Findings will be used to improve tools and instruments to detect, visualise and facilitate informal professional development networks in school organizations.

Keywords
Networked Learning, Social Network Analysis, Professional Development Networks, Team Learning

Introduction

In recent years an extensive body of research has emerged that focuses on concepts describing how teacher learning can be embedded in daily practice. These concepts underline the importance of the social context for teacher professional development and school improvement, and build on the learning opportunities the social environment has to offer (Bolam et al., 2005; Hord, 1997; Toole & Louis, 2002). In schools, professional development involves opportunities for teachers to share their expertise, learn from peers, and collaborate on real-world projects (Vrasidas and Glass, 2004). This approach to learning embraces the participation metaphor (Lave & Wenger, 199; Sfard, 1998) where learning is seen as situated, embedded and maintained in the daily culture of shared and connected practices and professional standards. These practices not only concern the practice of teachers' own classroom or school. Participation also means involving themselves with a larger, perhaps even a global, landscape of teaching practices (Wenger, 1998). Learning in this context is distributed (Salomon, 1993) stretched over a network of people (Bereiter, 1991). People use their networks as a social infrastructure to gain access to what it is they are looking for whether it is products/materials, knowledge and new colleagues. Networked learning, in our approach, is a form of informal learning situated in practice, where people rely strongly on their social contacts for assistance and professional development (De Laat & Coenders, 2011; Jones, Asensio, & Goodyear, 2000). Recent research has provided evidence linking networked learning to an array of positive outcomes, including teacher professional development, team learning, student performance and school improvement (Coburn & Russell, 2008; Earl & Katz, 2007; McCormick et al., 2010; Moolenaar, Daly, & Sleegers, 2010; Penuel et al., 2010; Pil & Leana 2009). A social network is an expression of the collection of individuals that are connected by relations (Wasserman & Faust, 1994). Studying the structure of the contacts between people gives insight in the manner in which information is exchanged within an organization. Information exchange is basal to learning and we assume that the structure of contacts represents who learns from whom. This structure can be studied by a method called Social Network Analyses (SNA). Additionally, valuable information can be derived from the topics of the contacts. This indicates what is learned within this social network.

Important measures that are studied within SNA are, for instance, density, degree, betweenness, and cohesion of the network (Wasserman & Faust, 1994). The density of a network is a measure that reflects the proportion of all possible contacts that can be utilized (Wang & Li, 2007). A larger density indicates more contacts between people and hence more possibilities for learning. The degree reflects the number of contacts that a person has. A higher degree reflects more contacts. The degree can also be expressed as the average degree of a network. This gives an indication of the average number of contacts that a person within the network has (Wang & Li, 2007). This measure is strongly related to the density and therefore, a higher degree is beneficial for more learning. Betweenness reflects whether the person acts as gatekeeper or bridge between people or groups of people. These persons are important in a network because they can link several groups together, but they also have much power because they can influence the flow information between those (groups

ISBN 978-1-86220-283-2

of) people (Wang & Li, 2007). Thus, gatekeepers can determine what is learned by allowing information to flow from one subgroup to the other or withholding information. Cohesion is an important centrality measure because it reflects the number of subgroups (cliques) within a larger group. Information within a clique can be learned in depth, but if the information remains within the clique, the other members of the group do not benefit.

SNA is often applied to networked learning to study the nature of the contacts between people (See De Laat, Lally, Lipponen & Simons, 2007 for an overview). In this study we used SNA to capture the structure of contacts between teachers that are clustered in teams at a school, which is a recent development in school organization in the Netherlands (Kommers & Dresen, 2010). The definition of a team contains three factors: (1) a team is a working group that exists within the context of a larger organization (i.e., the school), (2) it is clearly defined who is a member of the team (in school for instance based on the grade they teach), and the team members share a responsibility for a team product or service (Edmondson, 2002). The teams that were studied in the current paper were newly formed teams, namely, during the current school-year. The learning modes (see next paragraph) of the teams was unknown. However, the school staff expected that there would be more contacts between the teams (influenced by contacts between teachers that teach the same subjects and the contacts in the previous years) than within the teams. The school staff stimulated more sharing of information within the teams (i.e., a higher density within the teams than between the teams). With SNA, this can be studied.

This design is ideally suited for studying the impact of contacts within and between teams on professional development using SNA. Learning within a team consists of several learning processes including (re)framing, experimenting, crossing of boundaries (e.g., contacts with people that are no member of the team), and the integration of perspectives (different views). Learning within teams can be classified in four levels or stages: fragmented (i.e., on the individual level instead of group level), pooled learning (in which subgroups within the team learn collectively), synergistic learning (in which integration of different perspectives takes place), and continuous (in which there is spreading throughout the organisation) (Dechant, Marsick, & Kasl, 1993). In later work on team learning, these levels/stages are referred to as modes, because levels/stages imply an ascending development, whereas this is not necessarily the case for the levels/stages (and in the subsequent part of the paper referred to as 'modes') of team learning (Kasl, Marsick, & Dechant, 1997). The learning processes and learning modes described above are influenced by the structure of the contacts between people. Thus, to study the learning processes and learning modes, SNA is a useful tool and the centrality measures are suited to study this. For instance, the density and degree can be calculated to study whether a team operates in a synergistic (high density within and between teams, high degree within and between teams) and/or continues learning mode (high density and degree between teams) and the processes of crossing of boundaries (high density and degree between teams) and integration of views (high degree between teachers with different backgrounds). Cohesion can be studied by means of analyses of cliques, which can represent the mode of pooled learning.

We expected that the structure of the web of contacts within a team depended on several aspects. The aspects we focused on were special functionalities within the team and characteristics of teachers that influence the capability of the formation and maintenance of contacts. Special functionalities within the team are for instance the team leader or a coach for internship-teachers. These special functionalities require more intense contacts with other team members and this could lead to higher degree and betweenness for team leaders and higher degree and cohesion for coaches and internship-teachers. Internship-teachers are also more likely to have less contacts, based on their 'role'. They often spent less time at the school, which could lead to fewer contacts. Additionally, characteristics of teachers could influence their contacts. For instance, teachers that have past experiences with management-tasks, are probably more able to form and maintain social contacts because this was part of their (previous or during their spare time) function or more extravert personality types. These teachers, who are more socially active, could show a higher degree than other teachers. On the other hand, there might be teachers that are not as socially active, due to for instance illness or shyness. This could lead to a lower degree and in a web of contacts, they could be positioned at the edges of a social structure.

Based on these expectations we formulated the following hypotheses:

Hypothesis 1: Based on the SNA, the mode of the network (fragmented learning, pooled learning, synergistic learning, of continuous learning) can be established.

Hypothesis 2a: Teachers with a management function (i.e., team leader) within the team show a higher degree and a higher betweenness than other teachers without that function.

Hypothesis 2b: Teachers and internship-teachers show a higher degree and are more likely to be part of a clique (i.e., higher cohesion) than other teachers.

Hypothesis 3: Teachers with personal characteristics that are beneficial for maintaining contacts show a higher degree and a higher betweenness than teacher with characteristics that are not beneficial for maintaining contacts.

ISBN 978-1-86220-283-2

Method

Participants

All teachers of a school for Higher General Secondary Education (in Dutch: HAVO) and Pre-University Education (in Dutch: VWO) were asked to fill out a 'contactmap' (N = 135; See the Procedure and Instruments section for a more detailed description and the Appendix for an example of the contactmap). In total, 117 teachers filled out the contactmap (response rate = 86,7%; See Table 1 for the distribution of the teachers and response rates over the teams). The contactmap was part of the team meetings and, if possible, would be used to guide the contacts between teachers. The teachers were divided over six teams, depending on the grade they were teaching. Thus, teachers were not clustered according to subject they were teaching. Each team included a teacher that operated as team leader.

Table 1: Distribution of the teachers and response rates over the teams

Team	*N*	*n (completed)*	*Response rate*
A	31	22	71%
B	17	17	100%
C	33	30	91%
D	16	14	87.5%
E	19	16	84,2%
F	19	18	94.7%

Procedure and Instruments

During a team meeting, the participants filled out a contactmap in order to find out who is talking to whom and what they are learning about (De Laat, 2006). On this map they indicated for each relation (with another teacher), how often these contacts were (daily, weekly, or monthly) and the topic(s) of these contacts, to indicate a learning relationship.

The contactmap is filled out on a pre-printed paper sheet. On the front of the paper is a table with three columns. In the first column, digits are expressed that are coupled to the names of all team members. Those names are expressed in the second column. The third column is intended to fill out the topics of (learning of) the contacts. Underneath the digits in the first column are letters. The second column next to the letters is blank. Here, the names of teachers from the other teams with whom contacts are maintained can be written, including their (learning) topic.

On the back of the paper, a circle was drawn with three layers (See Appendix 1 for an example). In the inner layer, the digits and letters corresponding to the team members or teachers of the other teams with whom there was daily contact were written. In the middle layer, the digits and letters corresponding to the team members/teachers with whom there was weekly contact were written. In the outer layer, the digits/letters corresponding to the team members/teachers with whom there was monthly contact were written.

After data collection, the (learning) topics were clustered into categories by a researcher that was familiar with the school. The clustering was reviewed with the school to verify the correct division of (learning) topics that were present at the school (See Table 2 for an overview of the categories of topics).

Table 2: Categories of learning topics

Code	*Topic*	*Specification*
1	Students	Mentoring – dyslexia – classroom – homework – Magister (monitoring system for students – administration)
2	Teaching methodology - education	Grades – projects – curriculum– educational materials – external foundation for educational guidance – electronically learning environment – thesis guidance
3	Teaching methodology	Subject related matters
4.A	Organization-Students	Events – excursions – exchange

ISBN 978-1-86220-283-2

4.B	Organization-Team	Team matters – department
4.C	Organization-School	Organisational school matters – new school building – school activities – internships (students)
5	Personal development	Coaching – mediation – new teachers – systematic approach – internships (teachers) – special needs – specific professionalization
6	Private	
7	Other	General matters – job-related – not classifiable

Statistics

The data of the contactmap was entered in Excel and analyzed in UCI-net (Borgatti, Everett, & Freeman, 2002).

Missing values. Not all data of all 117 filled out contactmaps could be used. For the present study, only the data of the teachers that filled out the digits/letters in the layers of the circles were included. By filling out the digits/letters in the circles, they indicated with whom they had contact and the frequency of these contacts. Excluded were (part of) the data of the teachers that: (a) had no indication of the frequency of the contacts (n = 1; for the analyses that required data on frequency), (b) had written groups of people (e.g., ICT-network members) in stead of the individual digits/letters of the teachers that we were not able to trace (n = 9; for analyses on contacts between teams), or (c) otherwise missing data due to for instance bad handwriting or procedural failures (n = 4).

To study the monthly contacts, all contacts that were indicated by a teacher were used, regardless of whether the indicated teacher reciprocated that contact. Hence, all monthly contacts did not have to be reciprocated contacts. However, the weekly and daily contacts were only included in the analysis if the contacts that were indicated were actually reciprocated by the indicated teacher on the same frequency or more often. Thus, a contact that was indicated to be weekly by teacher A, but daily by teacher B was treated as a weekly contact. In a similar vain, contacts that were indicated with teachers that had not filled out a contactmap were omitted from these analyses because these are, per definition, not reciprocated. Hence, less data was available for the weekly and daily contacts as compared to the monthly contacts.

Analyses. Social Network Analyses (SNA) were performed to study the centrality measures on the level of the teacher and on the level of the team. The centrality measures used in the current study were density of the contacts within the team and average degree of the team and degree per teacher. Density is calculated: all indicated contacts / all possible contacts. Degree per teacher is calculated: sum of all indicated contacts. Average degree per team is calculated: sum of the degrees per teacher / number of teachers in the team. In further (visual) analyses of the network-drawings we checked the number of cliques and bridge functions. Additionally, we tallied the number of within team contacts and between team contacts and the number of times that a particular topic was mentioned. For each team, their ‘web of contacts’ was visualized and a selection of centrality measures (betweenness) was calculated. These visualisations and SNA-outcomes were reviewed by a researcher and discussed with the school to explain and declare the findings.

Visualisations were made from monthly, weekly and daily contacts. It appeared that monthly contacts were indicated by almost all team members with the other team members. Hence, these visualisation were very dense webs of contacts (and hence less informative). These will not be described in more detail in the current study.

In order to reduce space in this paper, we are not able to show all findings of the six teams. We therefore chose the visualisations that incorporated the most striking findings. Those are: weekly and daily contacts of team C en weekly and daily contacts of team F. The names of the team members are anonymous. However, for teams and schools, all visualisations are relevant because they give information about the flow of information within and between their teams and the modes of learning within the team. Note: the weekly contacts include the daily contacts. Even though we chose to show data for teams C and F only, the other teams showed similar results, however, these results were more moderate in nature.

Results and Discussion

We studied the within and between team contacts of teachers of a school for secondary education by use of social network analyses (SNA). Our assumption was that the structure of the web of contacts reflected the modes of the learning processes within the teams and that the contacts depended on the functions and the characteristics of the team members.

ISBN 978-1-86220-283-2

First, we compared overall centrality measures between the teams to study our first hypothesis: Can SNA indicate the learning mode of a team (see Table 3 for the centrality measures). Team C shows for weekly as well as for daily contacts, lower density scores than team F. This indicates that there are more contacts within Team F than in Team C. This could indicate that team F is in a high synergetic learning mode. A closer look into the contacts between teams (not described in the current study) shows that Team C has proportional more contacts with other teams than Team F. This could explain the lower number contacts within the team and could indicate that this team is in a higher continuous learning mode. For the school this is relevant information because it gives insight in what teams are dense in their contacts within the team, but have fewer contacts outside of their team. Information can be shared within the team in great detail, but it does not reach the other the other teams. This can lead to isolated information exchange, which is not beneficial for the other teams and the school. Stimulation of contacts between the teams (for Team F) is a recommendation for more information exchange within the school. Team C has fewer contacts within the team, which can lead to more shallow information exchange within the team. The stimulation of more within team contacts could lead to a deeper information exchange with team members. The average degree is related to the density and shows that members of Team F have on average more contacts with each other than members of Team C. The number of cliques (cohesion) shows that only for daily contacts in Team C, there are isolated subgroups of teachers that exchange information with each other, but not with other subgroups of teachers. This could indicate that the daily contacts in this team function in pooled learning mode. In subgroups with dense contacts, information can be shared in depth, but if there is no input from other points of view, this can lead to a narrowed vision (no integration of different perspectives). Thus, contacts between subgroups are necessary for sharing information and for more diversity in vision. People that serve as bridges between subgroups can be useful for this purpose, but have a strong influence on what information is passed on and what information is not. Therefore, more contacts with other subgroups is to be recommended.

Table 3: Centrality measures per team, for weekly and daily contacts. Individual centrality measures are not reported (betweenness; to reduce space), however the ranking order of the degree per teacher can be derived from the size of the nodes in the visualisations

Measure	***Team C***		***Team F***	
	Weekly	*Daily*	*Weekly*	*Daily*
Density	20.66%	13.26%	67.82%	26.45%
Average degree	5.59	1.73	10.99	2.67
Cliques	1	4	1	1

Our next (sub)hypothesis (2.a) was that teachers with a management function (i.e., team leader) within the team showed a higher degree and a higher betweenness than other teachers without that function. In team C, we see in, both the weekly and the daily contacts, that teachers C18 and C28 have the highest degrees (largest nodes) (See Figures 1 and 2).

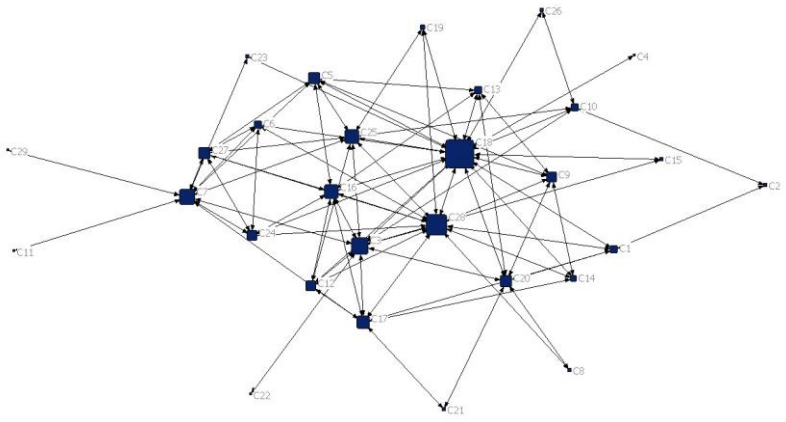

Figure 1: Visualisation of the weekly contacts of team C. The size of the nodes indicates the degree: larger nodes have a higher degree

ISBN 978-1-86220-283-2

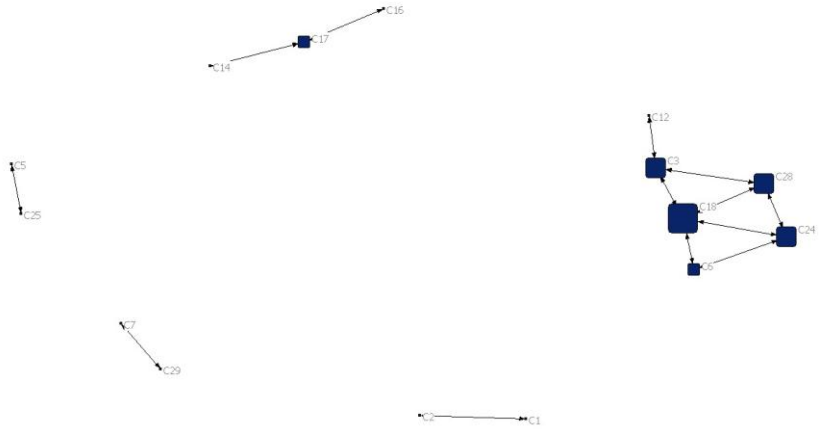

Figure 2: Visualisation of the daily contacts of team C. The size of the nodes indicates the degree: larger nodes have a higher degree

One of these teachers is indeed the team leader and the other teacher has a function that also requires to have frequent contacts with other team members. Team F, however, does not show such a strong difference between the team leader and other teachers in the weekly contacts (See Figure 3). As described above, this team has a higher density, which can explain why the team leader has not a deviant (higher) degree than the other team members. In the daily contacts, the team leader is more visible, namely teacher F11 (See Figure 4). He/she has the most central position (highest betweenness) and functions as a 'bridge' between other team members. The (dis)advantages of bridge-functions are mentioned above in the description of cohesion. This information is valuable for the school because it gives insight in which teachers serve as an important person for the information exchange. If teachers C18 and C28 in Team C disappear, the information exchange within the team will be majorly interrupted. However, if teacher F11 disappears in Team F, this will not have such a tremendous effect on the (weekly) information exchange within the team because other teachers can fill in the gap. For the daily contacts in Team F, this is of more influence, but this can be solved by less frequent contacts. The daily contacts of Team C also show a clique of contacts based on the 'function'of intership-teachers. The subgroup of teachers C1 and C2 exists of two teacher-internships. This is an exemplar of the, in the literature reported finding, that people with a similar background are more likely to have contacts (Moolenaar, 2010). Also, it shows that topic is an important factor in the formation and maintenance of contacts (coaching). Additional, teachers C5 and C25 form a subgroup based on the topic, namely subject related. Thus, besides function, topic determines contacts.

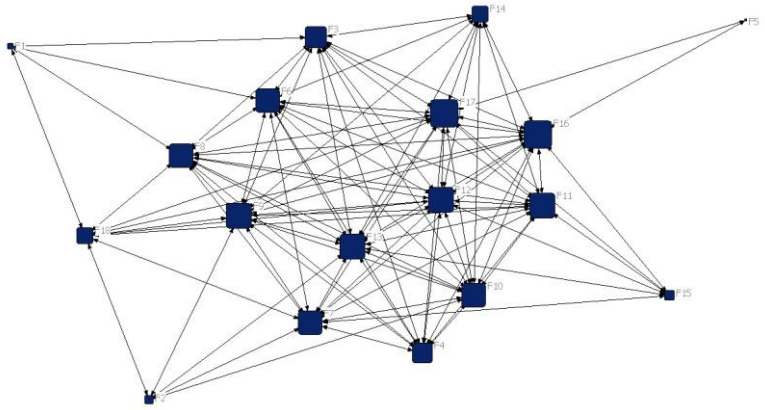

Figure 3: Visualisation of the weekly contacts of team F. The size of the nodes indicates the degree: larger nodes have a higher degree

ISBN 978-1-86220-283-2

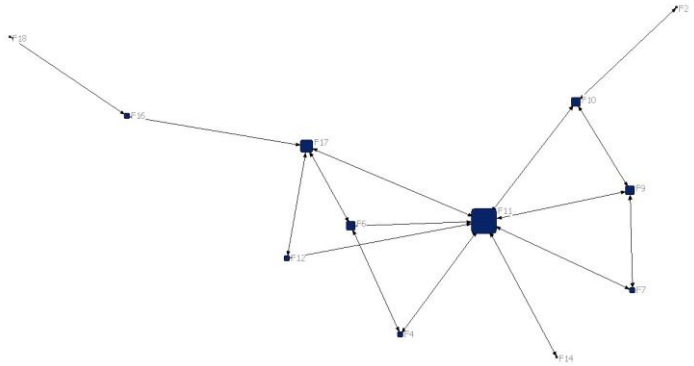

Figure 4: Visualisation of the daily contacts of team F. The size of the nodes indicates the degree: larger nodes have a higher degree

Our second (sub)hypothesis (2.b) was that teachers and internship-teachers show a higher degree and are more likely to be part of a clique than other teachers. This is most visible in the daily contacts of team C (See Figure 2): teacher C7 (coach) and C29 (internship-teacher) are such a clique. This is exemplary for other maps.

Our third hypothesis was that teachers with personal characteristics that are beneficial for maintaining contacts show a higher degree and a higher betweenness than teacher with characteristics that are not beneficial for maintaining contacts. This is indeed what the contact maps revealed (See Figure 1). Teacher C3 used to have a management function. He/she has a higher degree and betweenness than the average teacher within the network. He is more central to the network which enhances information exchange. On the other hand, teacher C4 has a position the map on the edge of the contacts. He/she has fewer contacts (lower degree). During the report to the school it appeared that this teacher is perceived as an 'outsider' by other team members. He/she has been sick for a long time because of a burn-out and he has another manner of teaching that does not match with other teacher's visions. Special attention should be paid to this teacher to make him/her a more active part of the information exchange flow.

Conclusions

Social Network Analyses (SNA) is, mostly, used to study contacts between people, for instance in the study of the networks during networked learning. In the current study, we used SNA to study the contacts between teachers of a secondary school that were clustered in teams, based on the learning relations they have with and between teacher teams. Information on the nature of these contacts within and between teams gives an indication of the information exchange within and between teams and the kind of learning within the team. It appeared that SNA can be used to indicate the dominant mode of team learning and learning processes characterized by the structure and topic of the social contacts. SNA can also be used to determine the web of contacts for each teacher personally and it turns out that a teachers functions in a school organization influences the relative number of (learning) contacts. For schools, SNA on the number and nature of contacts is valuable information because it helps to understand and uncover which teachers are influential in information exchange, what subgroups exist, and which teachers are on the edge of the contacts. In sum, it gives valuable information about informal social relationships that can be used to optimize the efficiency of communication structures that exist in schools as well as their potential for professional development and school innovation. This study is part of a larger long term research programme on the dynamics of teacher professional development networks funded by the Dutch government. The findings of this research will be used for improving tools and instruments to detect and visualise informal learning relationships (Korenhof, Coenders & De Laat, 2011; Schreurs & De Laat, 2011) and to further understand the kind of capital and value these networks produce (Wenger, Trayner & De Laat, 2011).

References

Bereiter, C. (1991). Implications of connectionism for thinking about rules. *Educational Research*, 20, 10–16.

Bolam, R., McMahon, A., Stoll, L., Thomas, S., Wallace, M., Greenwood, A., Hawkey, K., Ingram, M., Atkinson, A., & Smith, M. (2005). *Creating and sustaining effective professional learning communities.* Research Report 637. London, UK: DfES and University of Bristol.

Borgatti, S. P., Everett, M. G., & Freeman, L. C. (2002). Ucinet for Windows: Software for Social Network Analysis *Analytic Technologies*. Harvard.
Coburn, C. E., & Russell, J. L. (2008). District policy and teachers' social networks. *Education Evaluation and Policy Analysis, 30*, 203-235.
Dechant, K., Marsick, V., & Kasl, E. (1993). Towards a model of team learning. *Studies in Continuing Education, 15*(1), 1-14.
De Laat, M.F. & Coenders, M. (2011). Communities of Practice en netwerkenleren. In: J. Kessels, & R. Poell (Eds.), *Handboek human resource development: Organiseren van het leren [Handbook human resource development: Organising learning]* (pp. 417- 428). Houten, The Netherlands: Bohn Stafleu van Logum.
De Laat, M. F., Lally, V., Lipponen, L., & Simons, P. R. J. (2007). *Patterns of interaction in a networked learning community: Squaring the circle*. International Journal of Computer-Supported Collaborative Learning. DOI 10.1007/s11412-007-9006-4.
Earl, L., & Katz, S. (2007). Leadership in networked learning communities: Defining the terrain. *School Leadership & Management*, 27(3), 239–258.
Edmondson, A. (2002). Managing the risk of learning: Psychlogical safety in work teams. In M. West (Ed.), *International Handbook of Organizational Teamwork*. London: Blackwell.
Hord, S. (1997). *Professional learning communities: Communities of continuous inquiry and improvement*. Austin, TX: Southwest Educational Development Laboratory.
Jones, C., Asensio, M., & Goodyear, P. (2000). Networked learning in higher education: practitioners' perspectives. *Journal of the Association for Learning Technology*, 8(2), 18-28.
Kasl, E., Marsick, V., & Dechant, K. (1997). Team as Learners: A research-based model of team learning. *Journal of Applied Behavioral Science, 33*, 227-246.
Kommers, H., & Dresen, M. (2010). *Teamwerken is teamleren? Vormgeven en ontwikkelen van teams in het onderwijs*. Heerlen: The Netherlands: Ruud de Moor Centrum, Open University.
Korenhof, M., Coenders, M., & De Laat, M.F. (Eds.) (2011). *Toolkit Netwerkleren Primair Onderwijs* [Toolkit Networked Learning Primary Education]. Heerlen: Ruud de Moor, Open Universiteit.
Lave, J., & Wenger, E. (1991). *Situated learning- Legitimate peripheral participation.* Cambridge, UK: Cambridge University Press.
McCormick, R., Fox, A., Carmichael, P., & Procter, R. (2010). *Researching and understanding educational networks. New Perspectives on Learning and Instruction*. New York, NY: Routledge.
Moolenaar, N. (2010). *Ties with potential: Nature, antecedents, and consequences of social networks in school teams.* Universiteit van Amsterdam, Amsterdam, Nederland.
Penuel, W. R., Riel, M., Joshi, A., Pearlman, L., Kim, C. M., & Frank, K. A. (2010). The alignment of the informal and formal organizational supports for reform: Implications for improving teaching in schools. *Educational Administration Quarterly*, 46(1), 57-95.
Pil, F., & Leana, C. (2009). Applying organization research to public school reform. Academy of Management Journal, 56(2), 1101-24.
Salomon, G. (Ed.) (1993). *Distributed cognitions: Psychological and educational considerations*. Cambridge, UK: Cambridge University Press.
Schreurs, B., & De Laat, M.F. (Under review). *Network Awareness Tool: a web 2.0 tool to viausalize informal learning in organizations*. *Submitted to Computers in Human Behavior*
Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher,* 27(2), 4-13.
Toole, J. C. & Louis, K. S. (2002). The role of professional learning communities in international education." In K. Leithwood & P. Hallinger (Eds.), *Second International Handbook of Educational Leadership and Administration* (pp. 245-80). Dordrecht, The Netherlands: Kluwer.
Vrasidas, C., & Glass, G. V. (2004) (Eds.). *Current perspectives in applied information technologies. Online professional development for teachers*. Greenwich, CT: Information Age Publishing.
Wang, Y., & Li, X. (2007). *Social network analyses of interaction in online learning communities*. Paper presented at the IEEE International Conference on Advanced Learning Technologies (ICALT).
Wasserman, S., & Faust, K. (Eds.). (1994). *Social Network Analysis: Methods and Applications*. Cambridge, England: Cambridge University Press.
Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. New York, NY: Cambridge University Press.
Wenger, E., Trayner, B., & De Laat, M.F. (2011). *Promoting and assessing value creation in communities and networks: A conceptual framework.* Heerlen: Ruud de Moor Centrum, OU.

Appendix 1
Contact map